Jet Propulsion Laboratory
California Institute of Technology

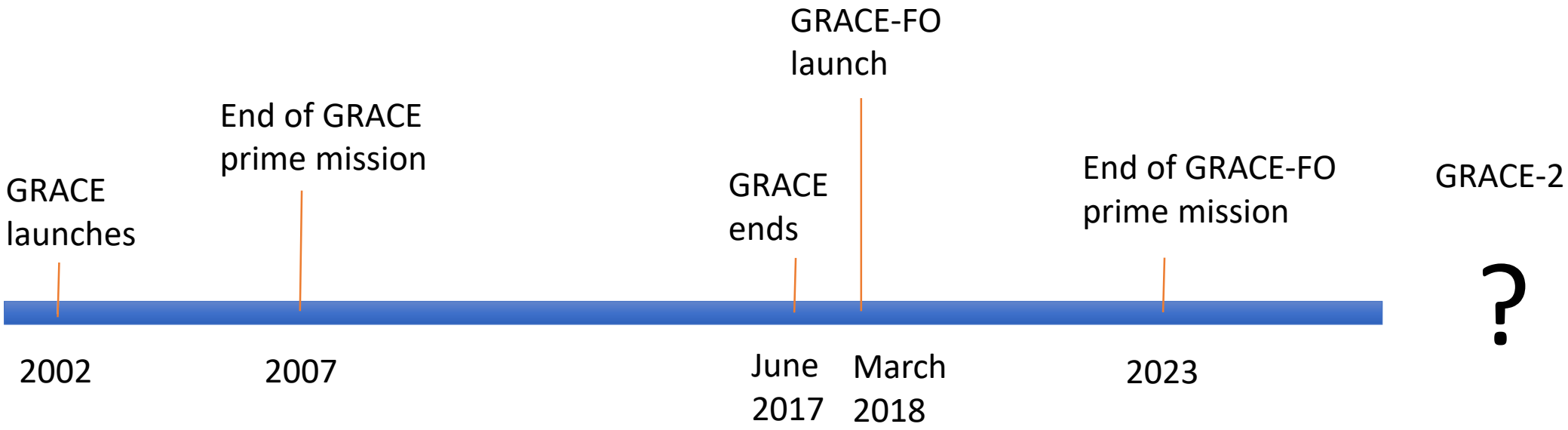
GRACE-2: Potential Improvements in Recovering Terrestrial Water Storage Variations

David N. Wiese[1]

[1]Jet Propulsion Laboratory, California Institute of Technology

October 25-27, 2017
EarthScope Hydro-geodesy Workshop
La Jolla, CA

Motivation

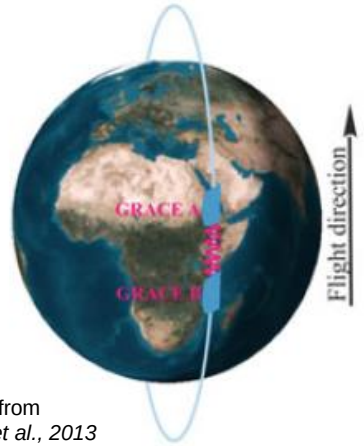


<u>Priorities for GRACE-2 (in order):</u>

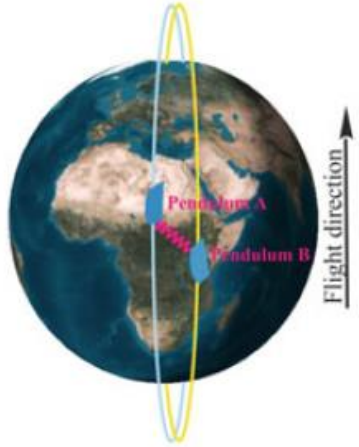
1) Continuity: separation of natural vs. anthropogenic effects
2) Improved data products
   - Spatial Resolution (GRACE: ~350 km)
   - Temporal Resolution (GRACE: ~1 month)
   - Accuracy (GRACE: 2 cm water height given the above)

How can we improve upon GRACE?

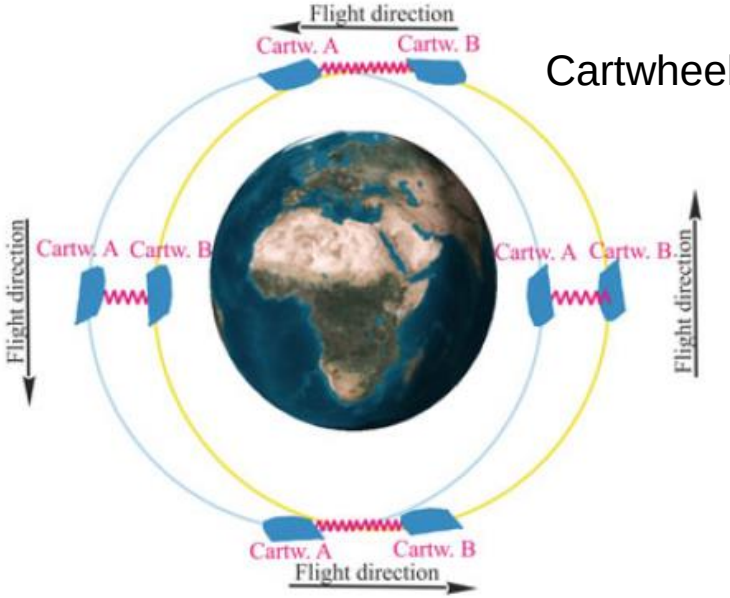
Collinear (GRACE)



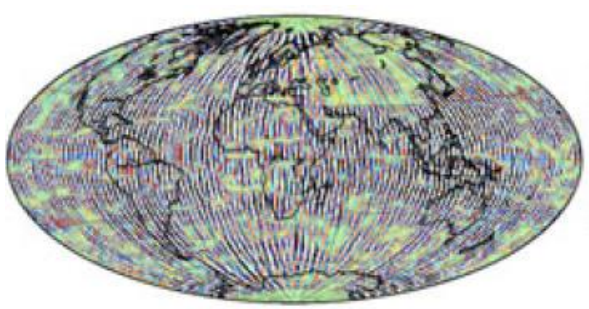
Pendulum

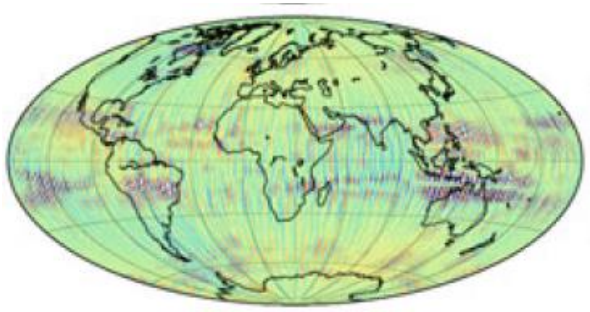


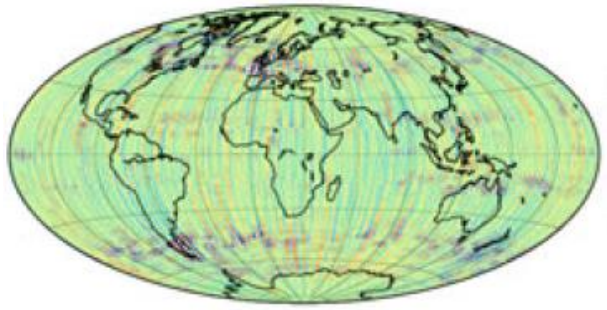
Cartwheel



Figures from
Elsaka et al., 2013







How can we improve upon GRACE?

J Geod (2009) 83:569–581
DOI 10.1007/s00190-008-0274-1

ORIGINAL ARTICLE

Alternative mission architectures for a gravity recovery satellite mission

D. N. Wiese · W. M. Folkner · R. S. Nerem

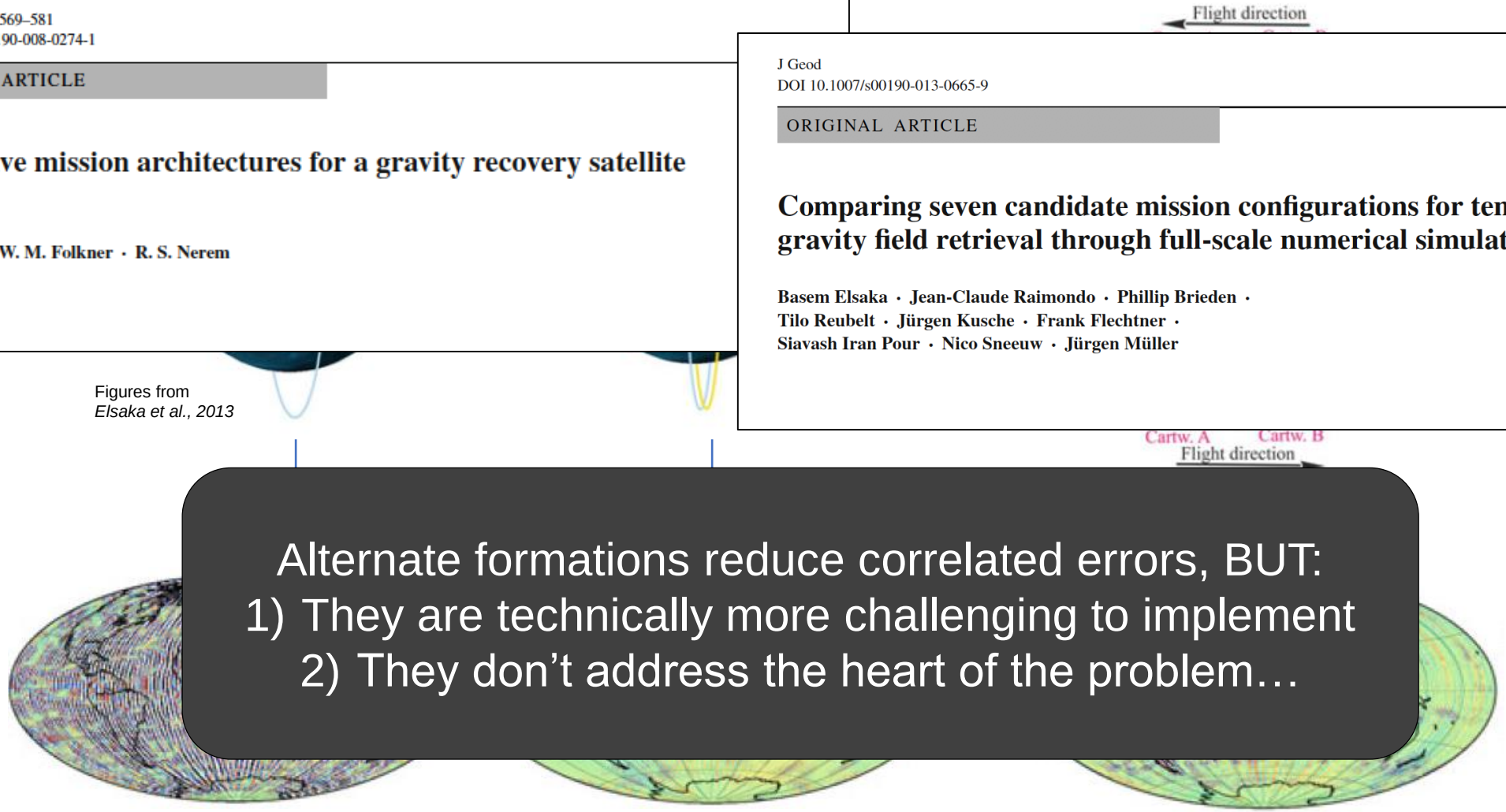
J Geod
DOI 10.1007/s00190-013-0665-9

ORIGINAL ARTICLE

Comparing seven candidate mission configurations for temporal gravity field retrieval through full-scale numerical simulation

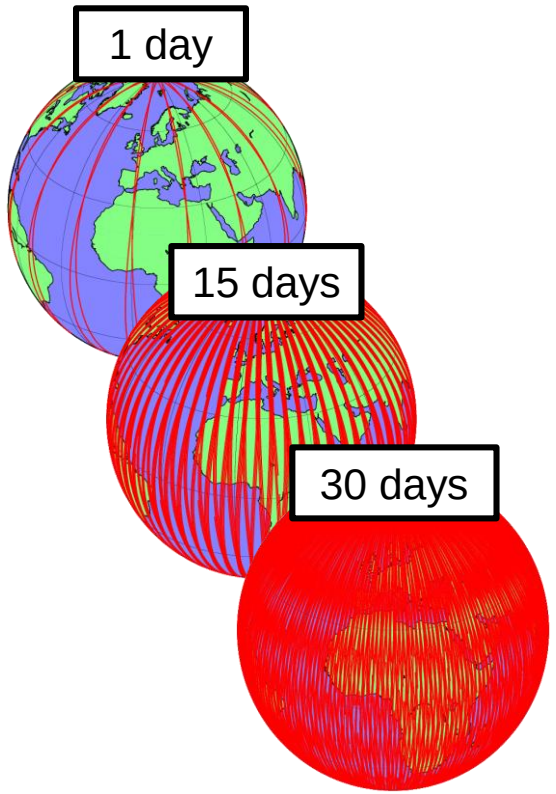
Basem Elsaka · Jean-Claude Raimondo · Phillip Brieden · Tilo Reubelt · Jürgen Kusche · Frank Flechtner · Siavash Iran Pour · Nico Sneeuw · Jürgen Müller

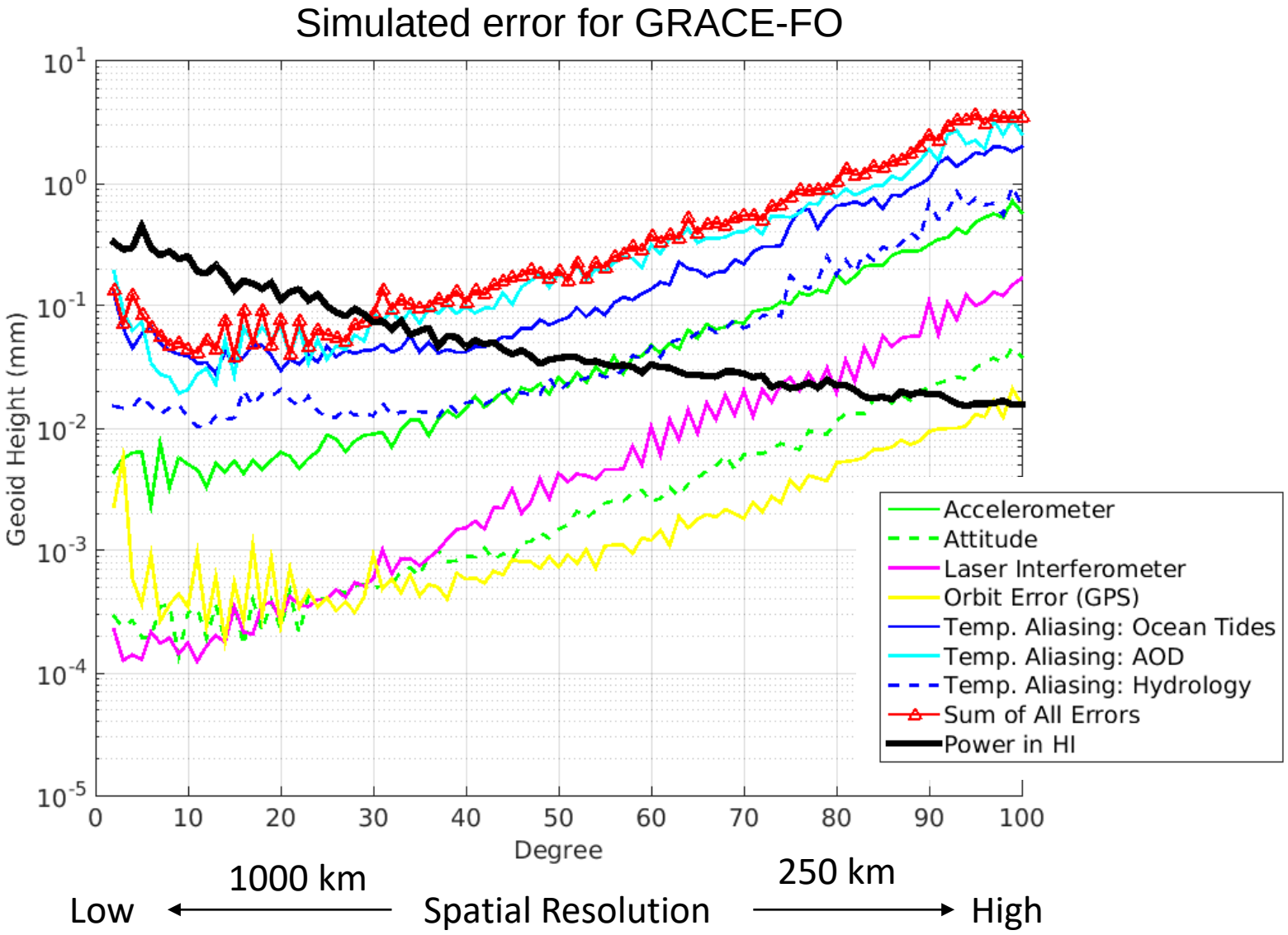
Figures from
Elsaka et al., 2013



Alternate formations reduce correlated errors, BUT:
1) They are technically more challenging to implement
2) They don't address the heart of the problem…

The main culprit: temporal aliasing errors





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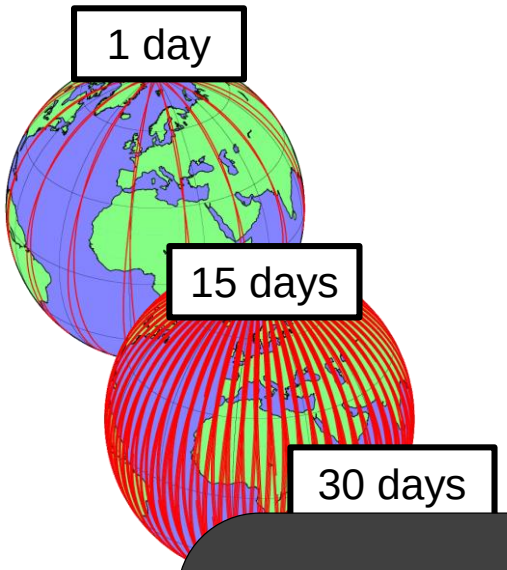
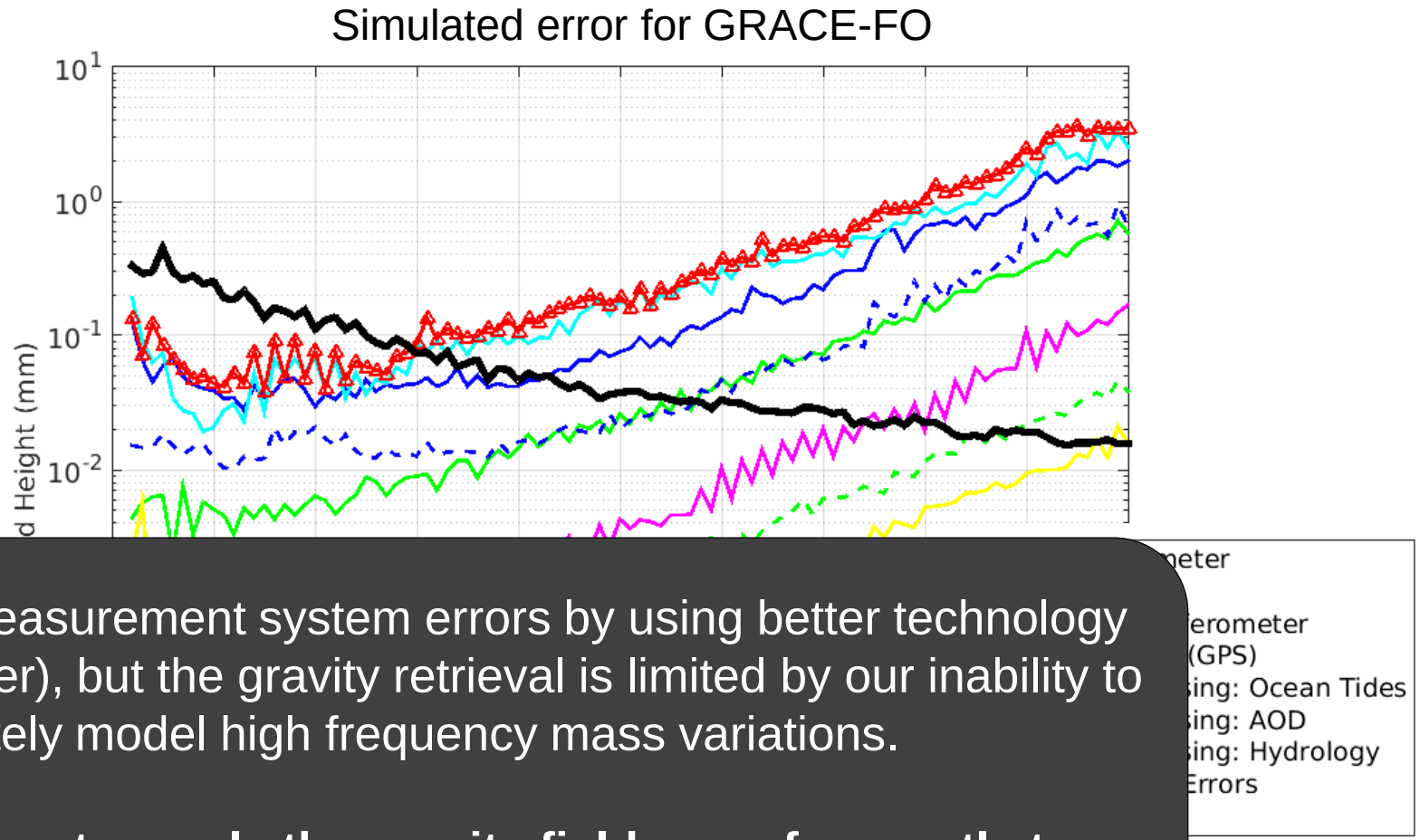




We can reduce measurement system errors by using better technology (laser interferometer), but the gravity retrieval is limited by our inability to accurately model high frequency mass variations.

Solution: We must sample the gravity field more frequently to measure, rather than model, high frequency mass variations

What if we had two pairs of satellites?

J Geod
DOI 10.1007/s00190-011-0493-8

ORIGINAL ARTICLE

Design considerations for a dedicated gravity recovery satellite mission consisting of two pairs of satellites

D. N. Wiese · R. S. Nerem · F. G. Lemoine

Optimize the Orbits

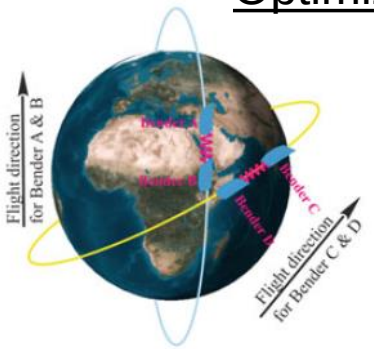
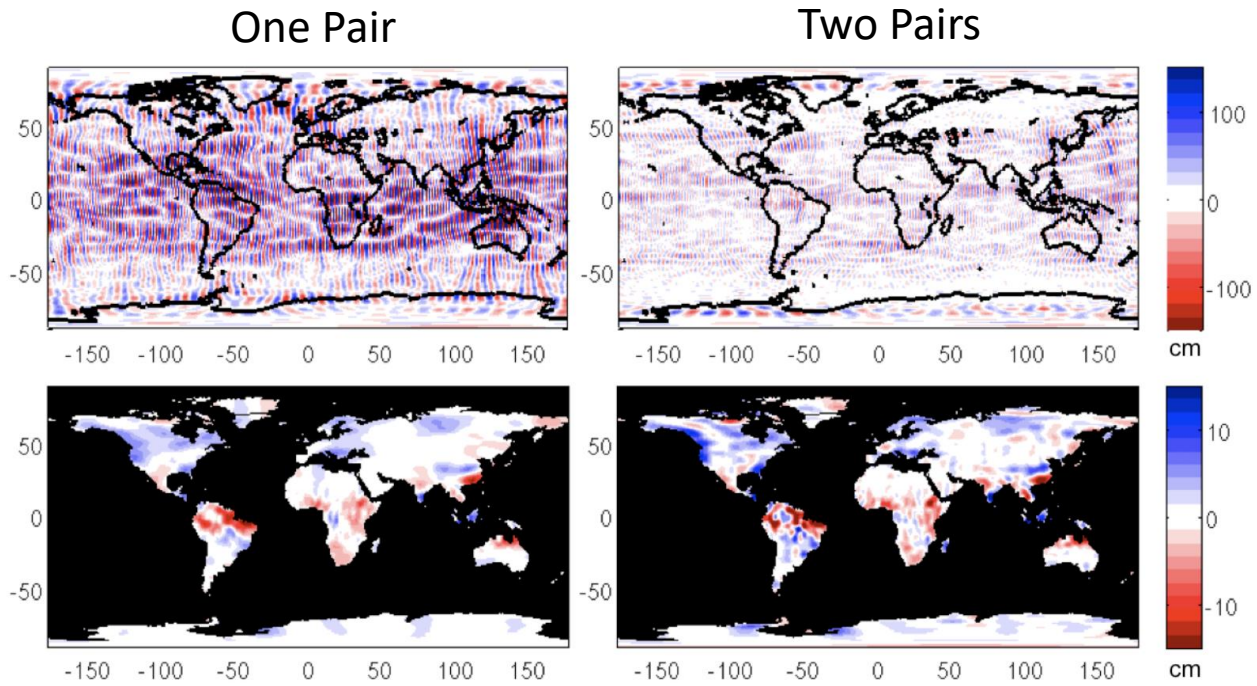


Fig. from *Elsaka et al.,* 2013

Pair 1: 90º inclination
13-day repeat period

Pair 2: 72º inclination
13-day repeat period



IGSWG Final Report, 2016

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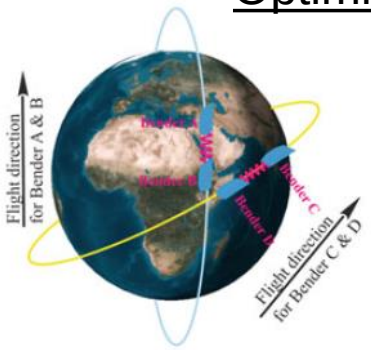

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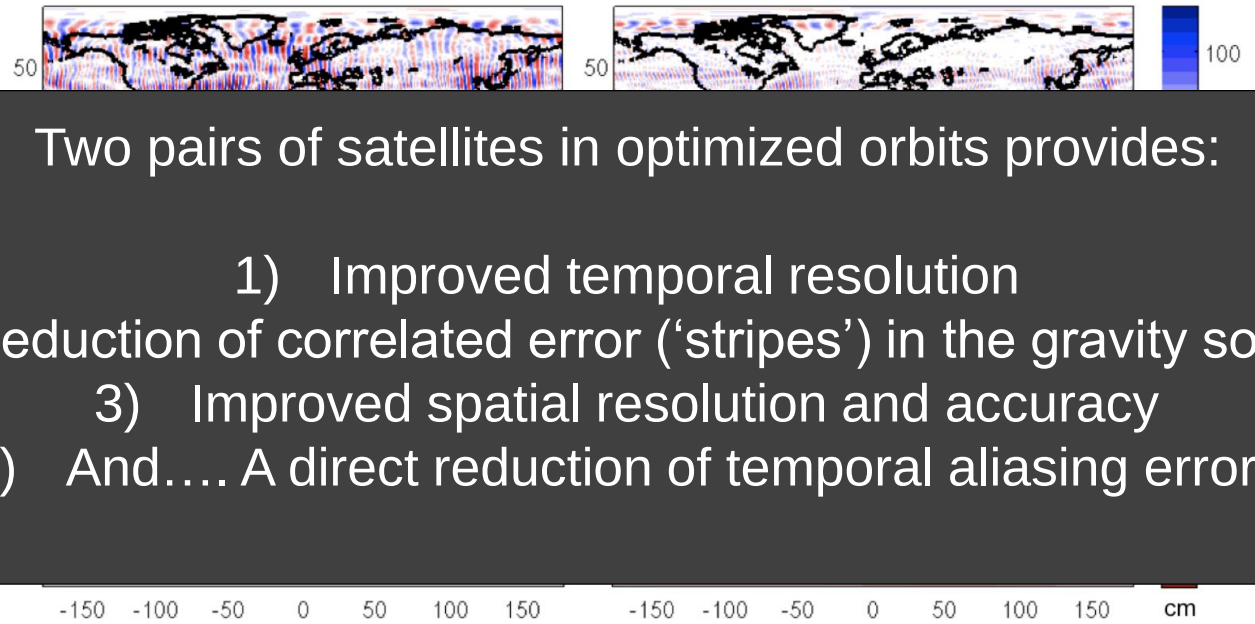
One Pair | Two Pairs

No postp

With po



Two pairs of satellites in optimized orbits provides:

1) Improved temporal resolution
2) Reduction of correlated error ('stripes') in the gravity solution
3) Improved spatial resolution and accuracy
4) And…. A direct reduction of temporal aliasing errors

IGSWG Final Report, 2016

A direct reduction of temporal aliasing errors

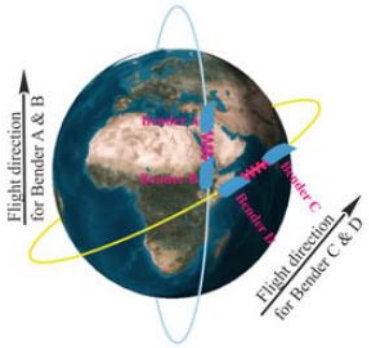
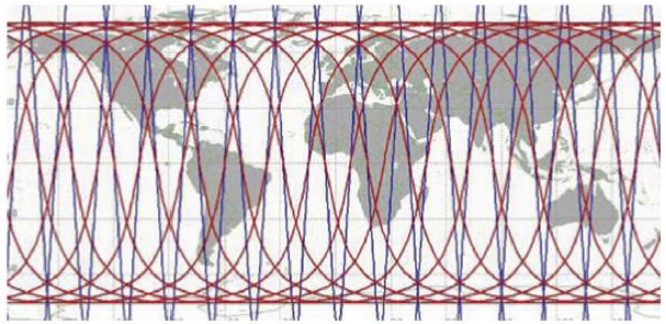
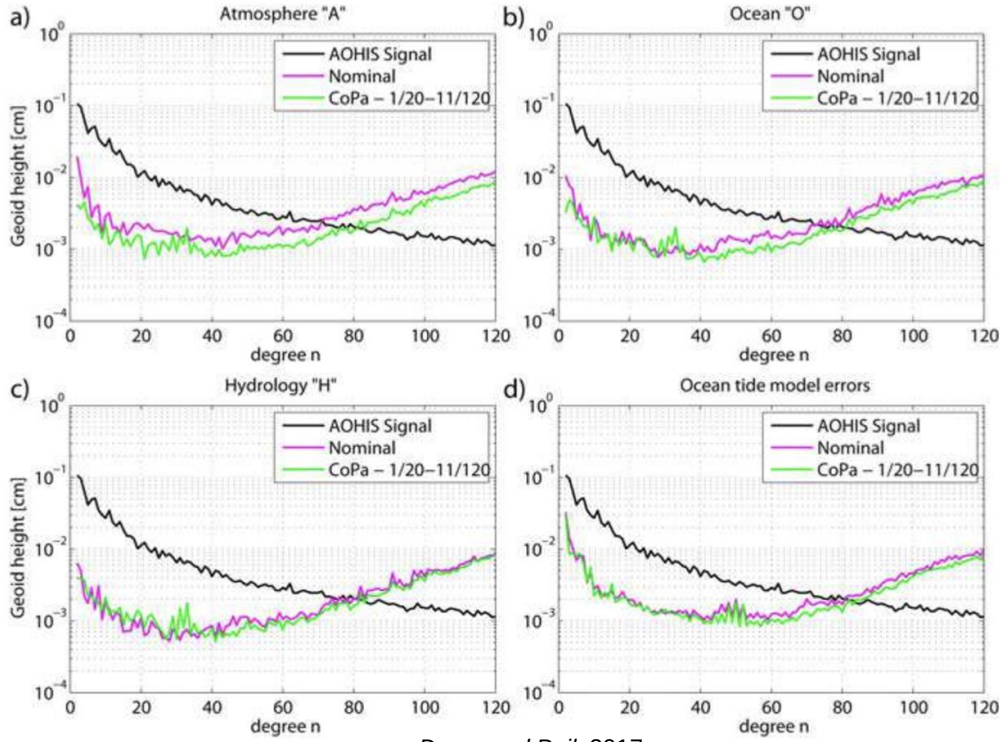


Fig. from *Elsaka et al.*, 2013

Groundtrack over 1 day



Wiese et al., 2011



Daras and Pail, 2017

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ADVANCES IN SPACE RESEARCH
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Estimating low resolution gravity fields at short time intervals to reduce temporal aliasing errors

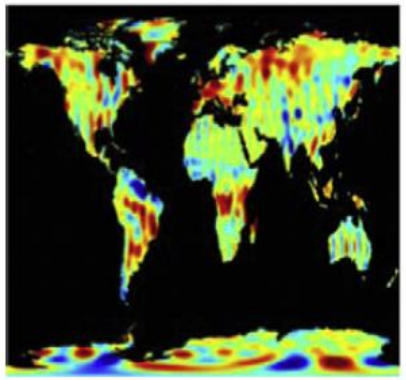
David N. Wiese [a,*], Pieter Visser [b], Robert S. Nerem [a]

AGU PUBLICATIONS
JGR
Journal of Geophysical Research: Solid Earth
RESEARCH ARTICLE
10.1002/2017JB014250

Treatment of temporal aliasing effects in the context of next generation satellite gravimetry missions

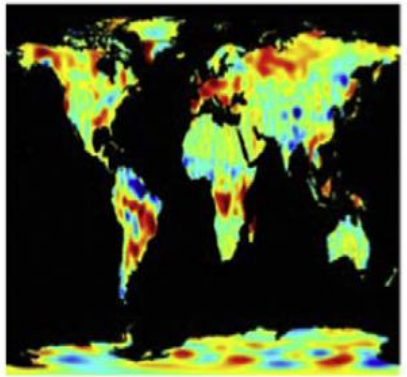
Key Points:
- NGGMs could retrieve the complete spectrum of Earth's nontidal geophysical processes
- Processing with the "self-dealiasing" approach leads to mitigation of

Ilias Daras[1] and Roland Pail[1]
[1]Institute of Astronomical and Physical Geodesy, Technical University of Munich, Munich, Germany

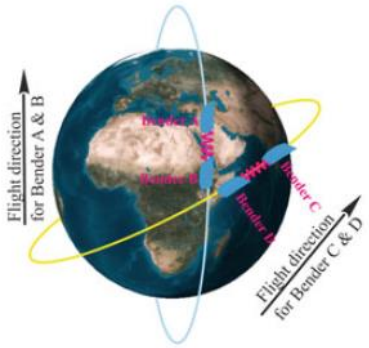


Estimate daily gravity fields

Reduce errors →



A direct reduction of temporal aliasing errors



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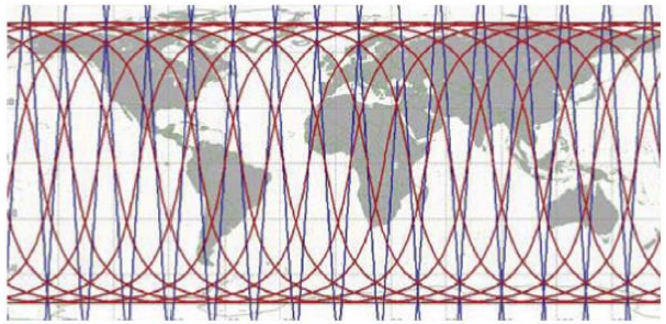

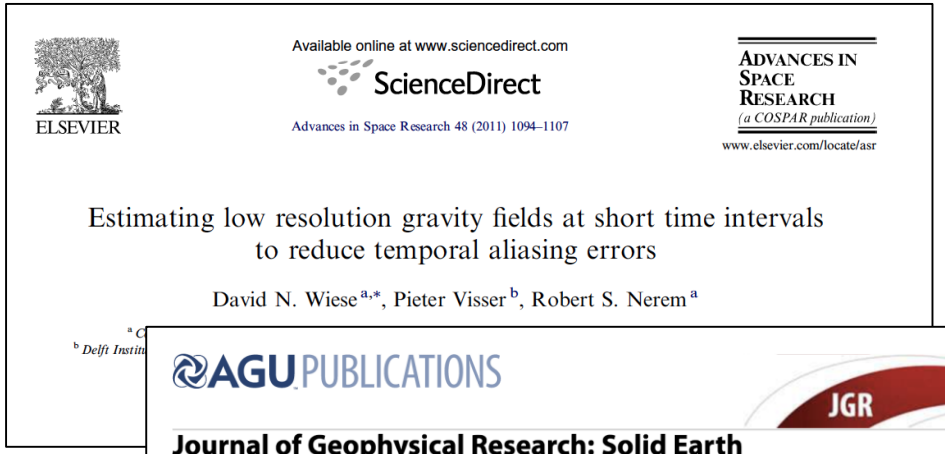

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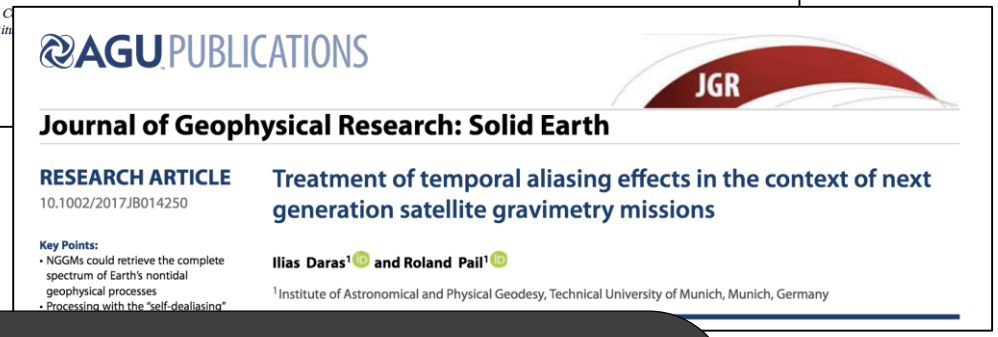
[b] Delft Institu



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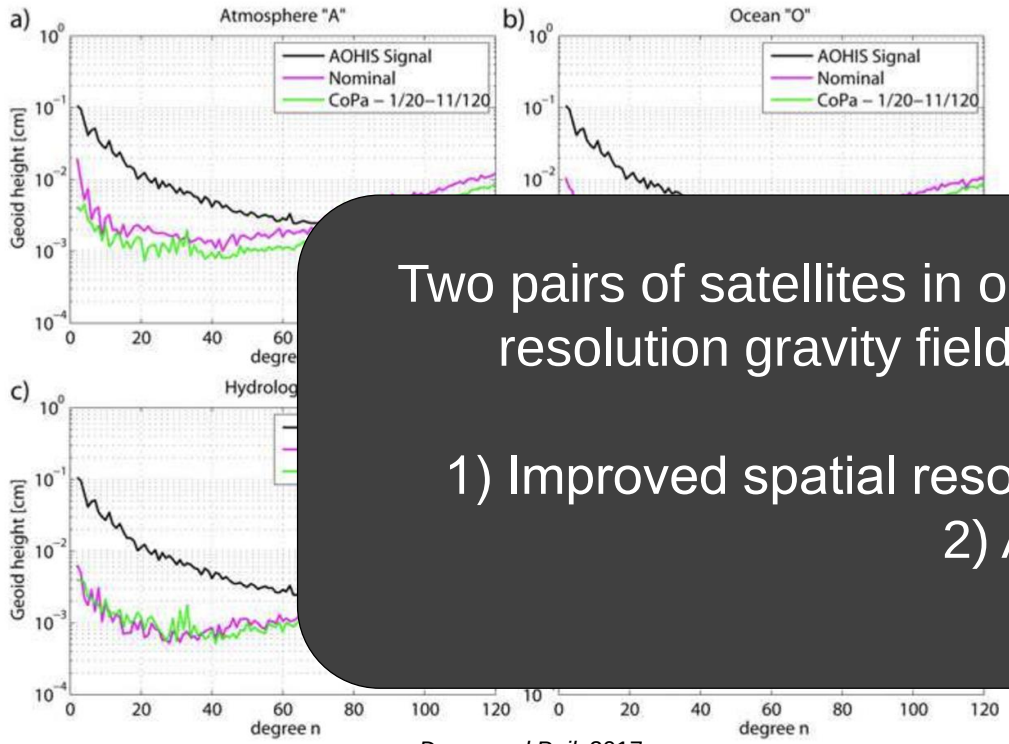
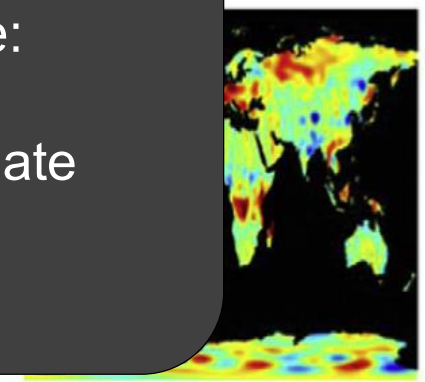


Daras and Pail, 2017

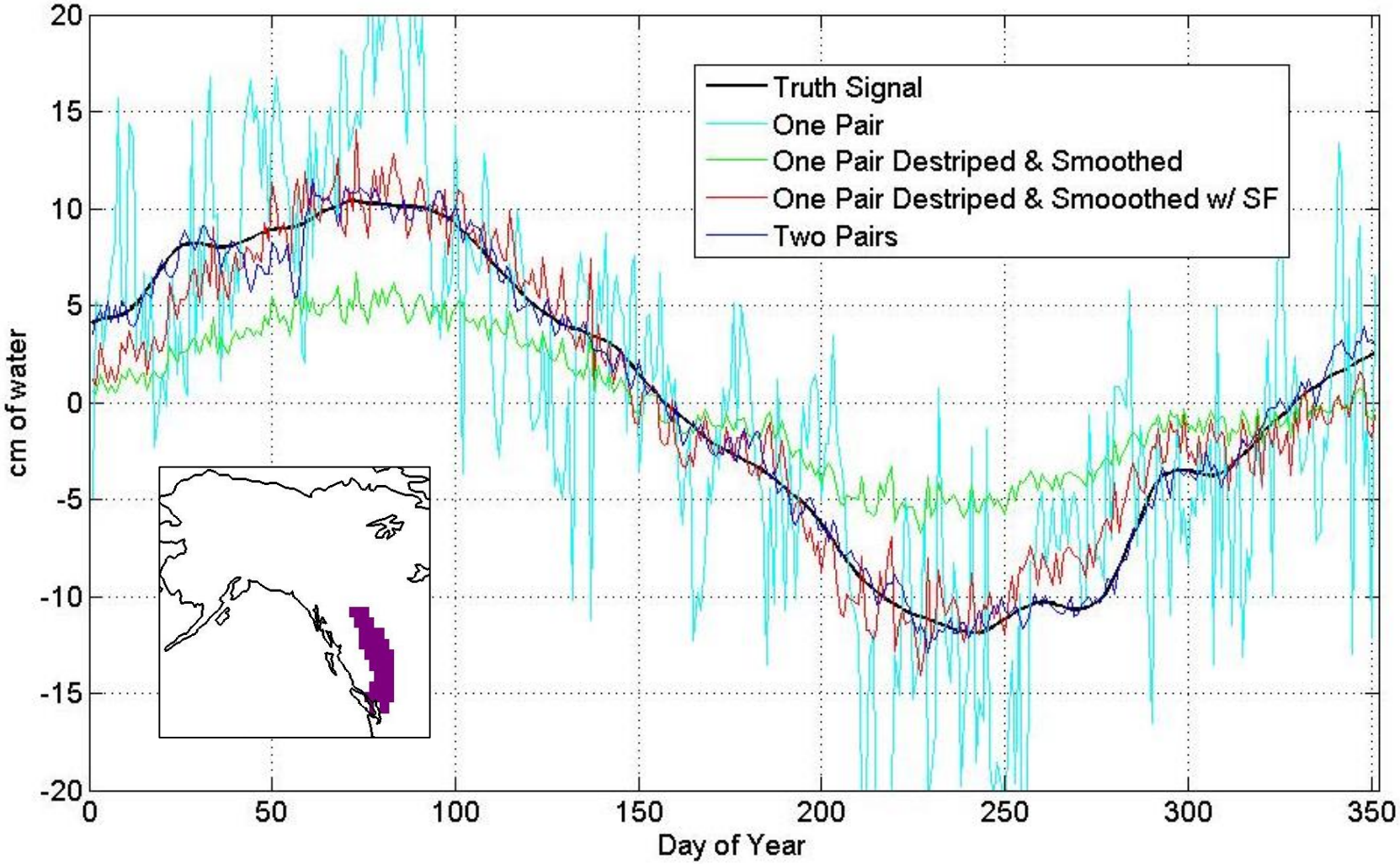
Two pairs of satellites in optimized orbits allows for estimation of low resolution gravity fields at short time intervals which enable:

1) Improved spatial resolution/accuracy in the 'monthly' estimate
2) A new data product



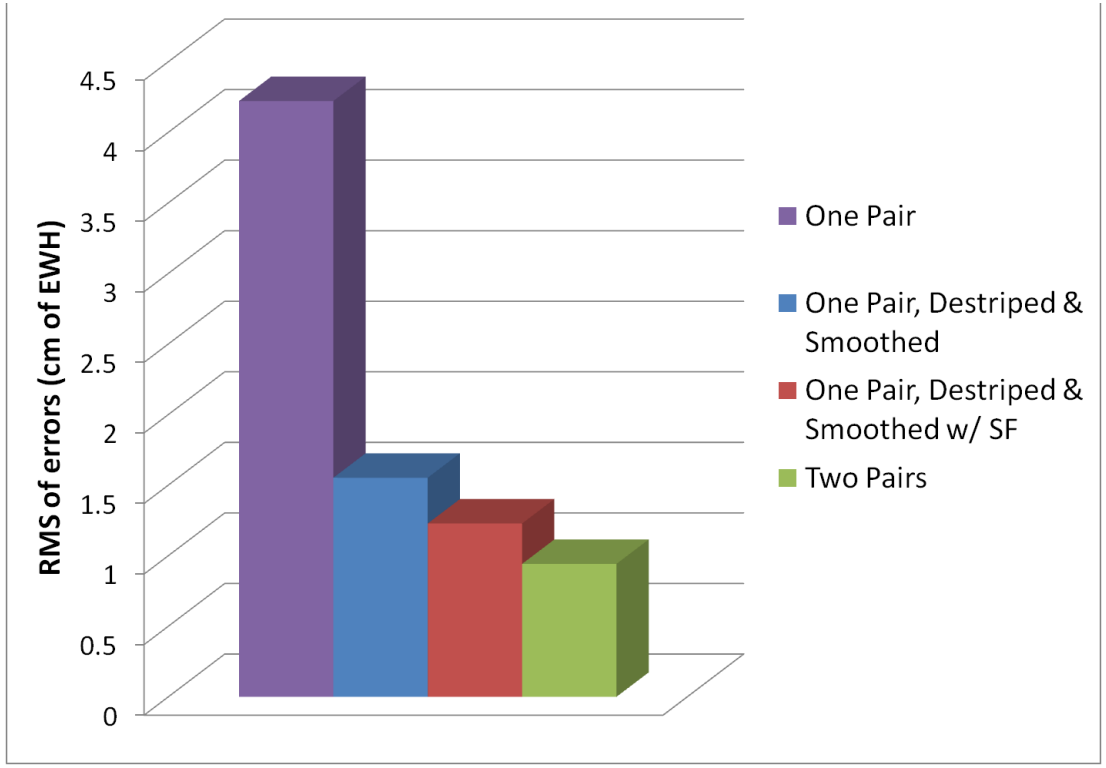
Potential improvements in data quality

Recovered total water storage over the Fraser Basin



Potential improvements in data quality

RMS of error over 50 largest hydrology basins



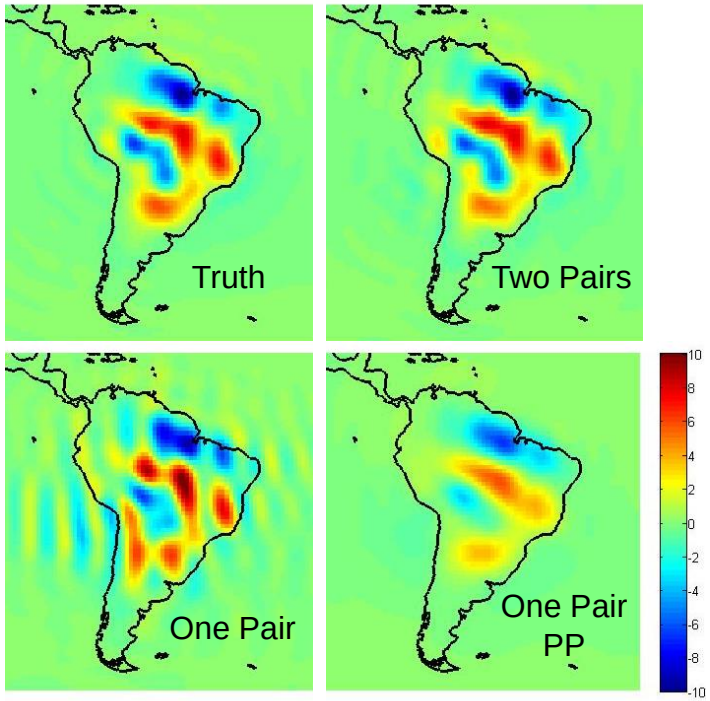
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, B11405, doi:10.1029/2011JB008375, 2011

Expected improvements in determining continental hydrology, ice mass variations, ocean bottom pressure signals, and earthquakes using two pairs of dedicated satellites for temporal gravity recovery

David N. Wiese,[1] Robert S. Nerem,[1,2] and Shin-Chan Han[3]

Received 18 March 2011; revised 13 August 2011; accepted 6 September 2011; published 19 November 2011.

Example recovery over South America

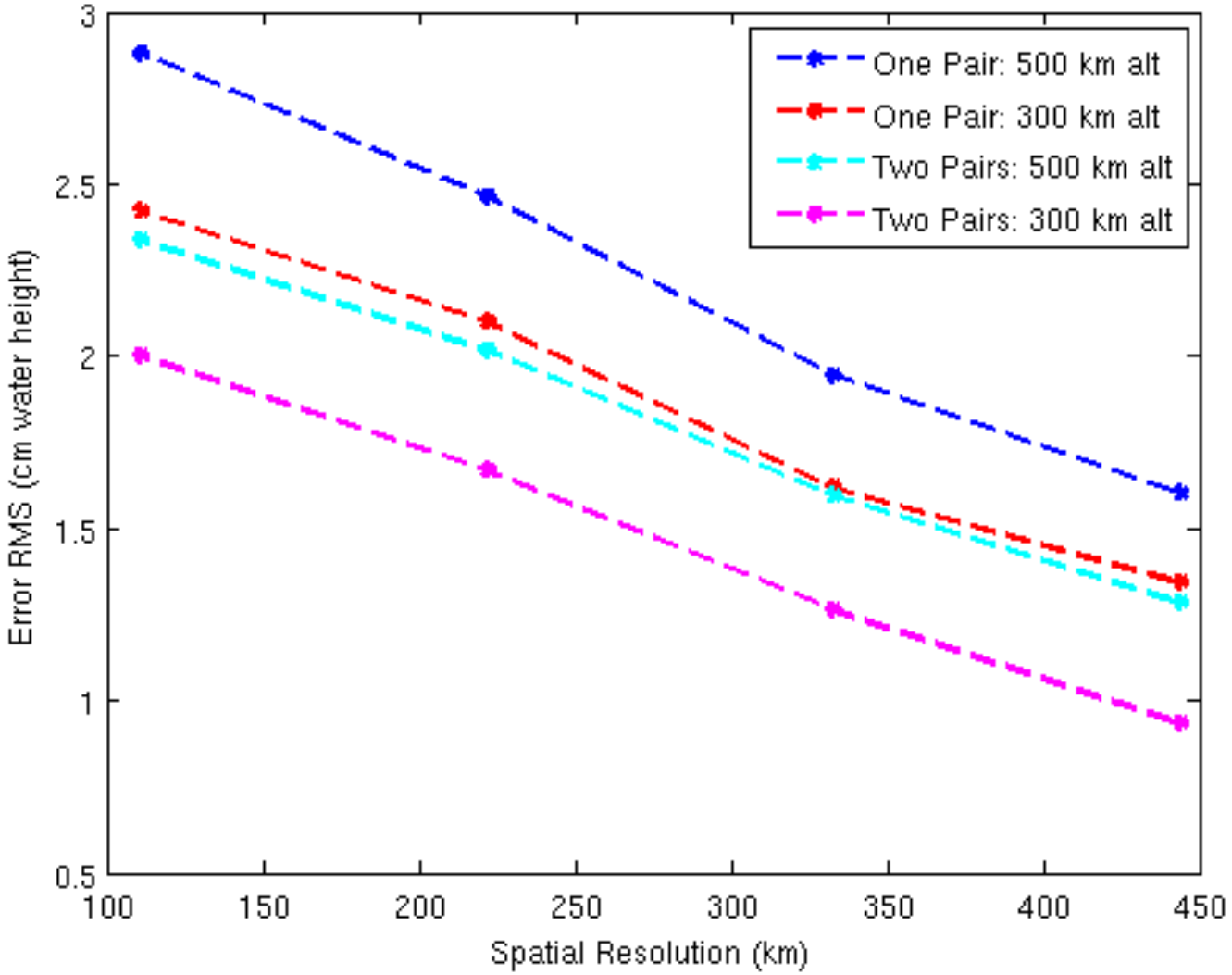


We find a **reduction in errors** of:

- **25% - 40%** for large hydrological basins
- **55% - 75%** for Greenland drainage basins
- **70% - 80%** for large ocean basins
- Recovering large earthquakes M8.0-M9.0

Spatial Resolution vs. Accuracy

Results are for recovering non-ice land hydrologic mass variations at monthly timescales



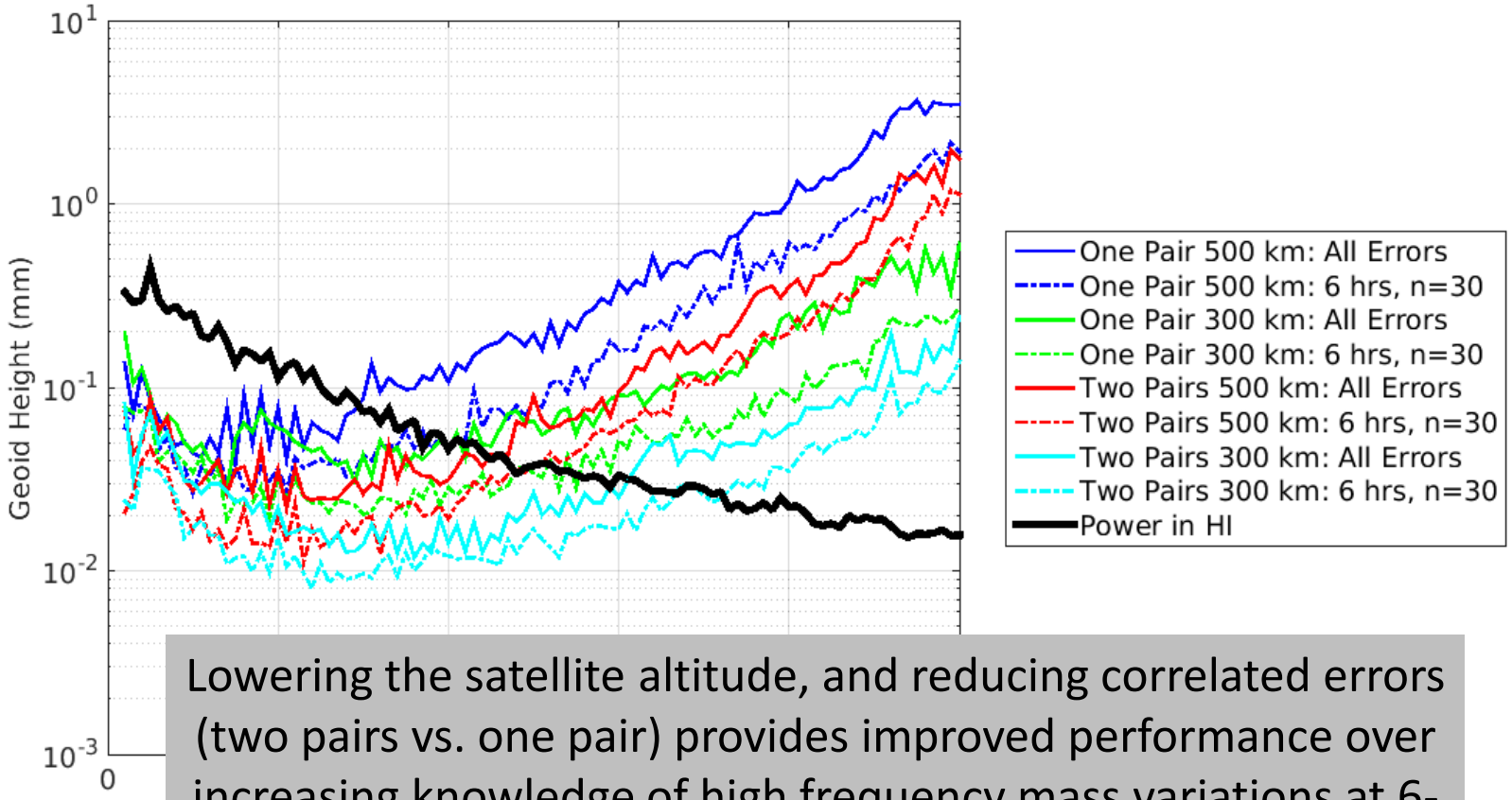
IGSWG Final Report, 2016

Concluding Thoughts

- GRACE-2 planning should start now
- Data continuity is the priority
- Two pairs of satellites offers an attractive option for improved data products
  - Reduced errors with increased spatial and temporal resolution
  - Likely would require international partnership
- More work needs to be done
  - Are there specific science questions that can be addressed with two pairs of satellites that are elusive for single pair architectures?
  - Does the improved data quality help data assimilation efforts?
    - ~100-200 km spatial resolution is still likely a limit for time-variable satellite gravimetry
  - What about satellite constellations?
    - Initial analysis indicates relatively minor improvements in spatial resolution and accuracy

Backup

Summary: 6-hourly 30 x 30



Lowering the satellite altitude, and reducing correlated errors (two pairs vs. one pair) provides improved performance over increasing knowledge of high frequency mass variations at 6-hourly, 667 km (n = 30) spatial scales